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**New Species of *Clavella* (Copepoda: Lernaeopodidae) Parasitic
on Japanese Rattails (Pisces: Macrouridae)**

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With Text-figures 1-6

Abstract Six new species of *Clavella* (Lernaeopodidae) are described based on the specimens recovered from the oral and gill cavities of Japanese rattails (Macrouridae) in the collection of Prof. Osamu Okamura kept at Kochi University in Kochi, Japan. They are: *Clavella gadomi* n. sp. from *Gadomus colletti*; *Clavella sokodarae* n. sp. from *Coryphaenoides nasutus* and *Coryphaenoides marginatus*; *Clavella longicauda* n. sp. from *C. marginatus*; *Clavella okamurai* n. sp. from *C. marginatus* and *C. nasutus*; *Clavella collaris* n. sp. from *Coelorhynchus paralleus* and *Coelorhynchus gilberti*; and *Clavella diversa* n. sp. from *C. paralleus* and *C. gilberti*. The host fishes were collected from deep-sea regions in Sagami Bay and Tosa Bay, and off Okinawa. Detailed discussions between each new species and its closest congeners are provided.

Introduction

In 1984 when the author visited Prof. Osamu Okamura's laboratory at Kochi University in Kochi, where the world's largest collection of Japanese deep-sea fish was kept, he examined all the rattails (or grenadiers, Macrouridae) in the collection and recovered from them 131 parasitic copepods belonging to *Clavella* (Lernaeopodidae, Poecilostomatoida). Subsequent studies of those specimens revealed that they belong to six new species.

Although about 80 species of lernaeopodids have been attributed to *Clavella* Oken, 1816 at one time or other, currently, only 25 of them are considered valid in the genus. Six of them are known from Japanese waters, namely, *C. adunca* (Strøm), *C. irina* Wilson, *C. ovata* Yamaguti, *C. perfida* Wilson, *C. recta* and *C. scombropis* Yamaguti. These Japanese *Clavella* are parasite of shallow, coastal fishes (Yamaguti, 1939; Gusev, 1951; Shiino, 1956). Therefore, the discovery of six new species of their congeners from Japanese deep-sea fishes is rather significant.

The copepod parasites were dissected and studied in lactic acid and the drawings were made with the aid of a camera lucida. All measurements given are in mm, unless stated otherwise. The holotypes together with various number of paratypes have been deposited in the U.S. National Museum of Natural History, Smithsonian Institution in Washington, D.C.

Description

1. *Clavella gadomi* new species

(Fig. 1)

Material examined. Thirty-one females attached to gills of 13 *Gadomus colleti* Jordan & Gilbert taken from Tosa Bay. Holotype and 10 paratypes deposited in the U. S. National Museum of Natural History; other specimens kept in the author's collection.

Female. Cephalothorax (Fig. 1A) subcylindrical, much longer than trunk and slightly inflated at base near attachment area of maxillae. Trunk squarish and somewhat flattened in ovigerous females but oval and thick in young, non-ovigerous females. Posterior margin of trunk also showing differences between young and old females (cf. Figs. 1B and 1C). Ovigerous female carrying a small genital process flanked at base on either side by a minute tubercle. Measurements of holotype: cephalothorax length 2.31, width 0.59; trunk length 1.51, width 1.63; egg sac lengths 3.43 and 3.39.

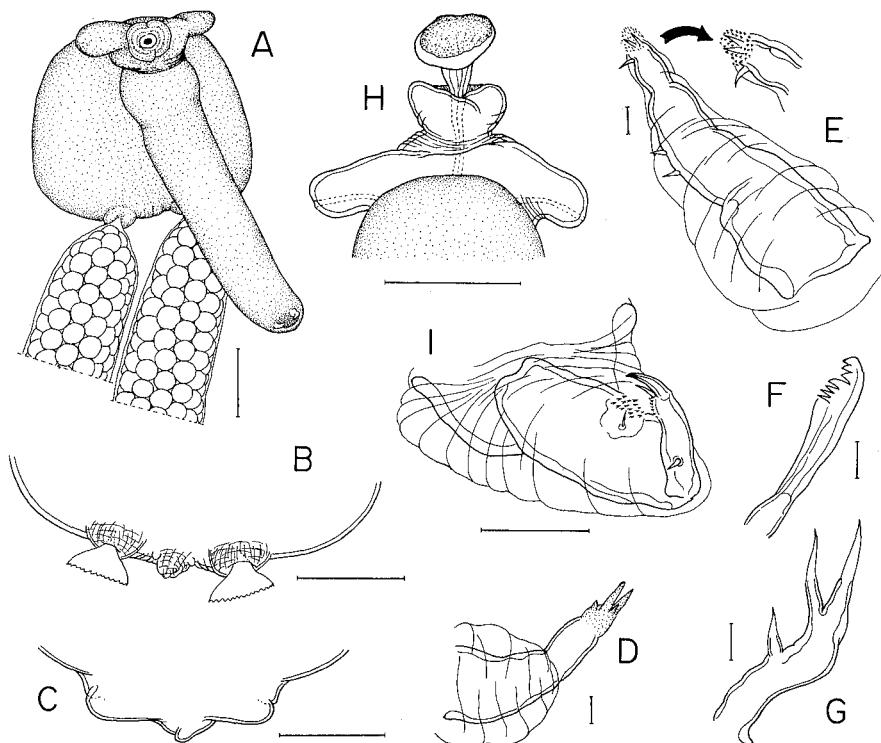


Fig. 1. *Clavella gadomi*, new species, female. A. Habitus, dorsal (cephalothorax in ventral view); B. Posterior margin of trunk, ventral; C. Posterior margin of young female, ventral; D. Antennule; E. Antenna; F. Mandible; G. Maxillule; H. Maxilla, posterior; I. Maxilliped. Scales: 0.5 mm in A, H; 0.05 mm in B, C, I; 0.01 mm in D, E, F, G.

Antennule (Fig. 1D) short, with inflated, unarmed base; terminal armature comprising 1 long seta, 1 obtuse process and 2 small tubercles. Antenna (Fig. 1E) long, uniramous, and indistinctly 3-segmented; proximal segment unarmed, middle segment with 2 setae on dorsal surface, and distal segment bearing 3 setae and a patch of denticles. Denticulous area of distal segment protruded terminally into a round process. Dental formula of mandible (Fig. 1F) P3-P1,B3. Maxillule (Fig. 1G) slender, without spinulose area; exopod bearing single seta and each terminal papilla of endopod tipped with a seta. Maxillae (Fig. 1H) short and completely fused, with large wing-like lateral protrusions carrying at their tip opening of excretory duct. Apical part of fused maxillae forming a distinct cup-like collar with manubrium passing through it into anchor. Bulla large, with funnel-shaped circular anchor. Maxilliped (Fig. 1I) 2-segmented; corpus robust, myxal area bearing a patch of spinules and 1 seta; subchela bearing single seta on proximal half and rows of spinules and a seta on inner-terminal margin; claw large, gently curved and sharply pointed.

Male. Unknown.

Etymology. The species name "gadomi" is taken from the genus name of the host from which the parasites were found.

Remarks. Of the 25 valid species of *Clavella* there are only three species bearing a small genital process like the present species from Tosa Bay. They are: *Clavella parva* Wilson, 1912, *Clavella recta* Wilson, 1915 and *Clavella bathyalis* Kazachenko & Avdeev, 1977. The last species is very different from *C. gadomi* in having a long trunk which is nearly 6 times longer than wide.

C. parva is known from both eastern and western North Pacific, including the Sea of Japan (Gusev, 1951; Kabata, 1970). The new species can be easily distinguished from it by (1) the structure of the maxillae (with a pair of large wing-like lateral protrusions and a large cup-like collar), (2) the absence of seta on the swollen, basal part of the antennule, (3) the terminal armature of the antenna (without bilobate tip), (4) the armature of the mandible (without secondary tooth), and (5) the exopod of maxillae bearing only one seta.

Clavella recta Wilson, 1912 was relegated by Kabata (1970) to a junior synonym of *C. parva*. However, later on, the same species was recognized as a valid species without offering explanation for new treatment or reference to the previous treatment (Kabata, 1979a). Based on the redescription of *C. recta* made by Gusev (1951), the new species can be distinguished from it by those structural details mentioned above except for item (5). *C. gadomi* and *C. recta* have the same type of maxilla with single element on the exopod and lacking the small inner seta on the endopod.

2. *Clavella sokodara* new species

(Fig. 2)

Material examined. Twenty-five females (some carrying a dwarf male) attached to gill rakers or floor of oral cavity of 12 *Coryphaenoides nasutus* Günther collected from Tosa Bay and Sagami Bay, and 3 females attached to floor of oral cavity of a *Coryphaenoides marginatus* Steindachner & Döderlein collected off Okinawa. Holotype and 10 paratypes (collected from Tosa Bay) deposited in the U.

S. National Museum of Natural History; other specimens kept in the author's collection.

Female. Cephalothorax (Fig. 2A) subcylindrical, much longer than trunk and bearing rather prominent cephalic shield. Trunk short and wide, with egg-sac attachment area distinctly set off from trunk proper and carrying posteriorly a long genital process (Fig. 2B). Measurements of holotype: cephalothorax length 2.16, width 0.36; trunk length (not including genital process) 1.19, width 1.61; egg sac lengths 1.59 and 1.68.

Antennule (Fig. 2C) indistinctly 4-segmented; first (largest) and third (smallest) segments unarmed, second segment carrying a short, obtuse element and terminal segment tipped with 5 elements. Antenna (Fig. 2D) much larger than antennule,

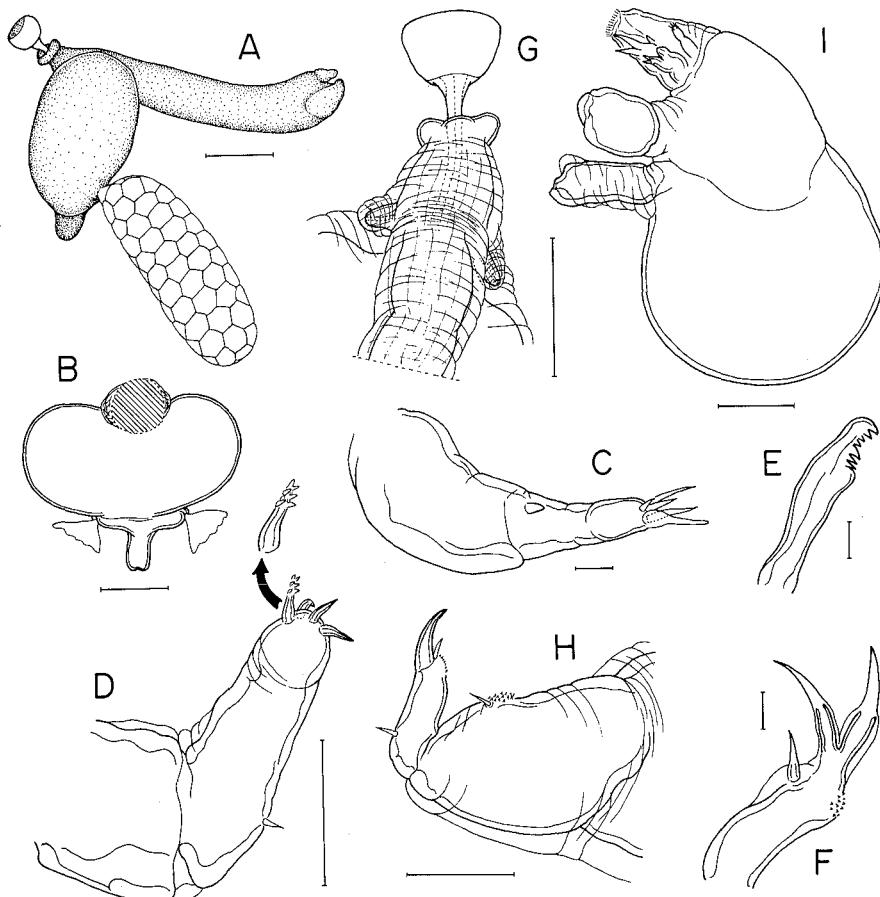


Fig. 2. *Clavella sokodara*, new species. Female: A. Habitus, lateral; B. Trunk, dorsal; C. Antennule; D. Antenna; E. Mandible; F. Maxillule; G. Maxillae, anterior; H. Maxilliped. Male: I. Habitus, lateral. Scales: 0.5 mm in A, B, G; 0.01 mm in C, E, F; 0.05 mm in D, H; 0.1 mm in I.

uniramous and indistinctly 3-segmented; proximal segment unarmed, middle segment with 1 seta on dorsal surface, and small terminal segment tipped with 3 sharp, spiniform processes and 1 denticulate process. Dental formula of mandible (Fig. 2E) P4-P1,B2. Maxillule (Fig. 2F) short, with patch of spinules on disto-inner surface; exopod bearing single seta and each terminal papilla of endopod tipped with a seta. Maxillae (Fig. 2G) short and completely fused, with moderate size lateral protrusions carrying at their tip opening of excretory duct. Collar prominent and anchor of bulla cup-shaped, with high side-wall. Maxilliped (Fig. 2H) 2-segmented; corpus robust, with myxal area bearing a patch of spinules and 1 seta; subchela bearing an outer seta subproximally and rows of spinules and a seta on inner-terminal margin; claw large, gently curved and sharply pointed.

Male. Body (Fig. 2I) dwarf, with short, oval, posteriorly rounded trunk not divisible into cephalothorax and trunk. Length of body 471 μ m. Appendages mostly as in female, except for prehensile maxillae.

Etymology. The family name of Macrouridae in Japanese is "sokodara", from which the name of this new species was taken.

Remarks. There are seven species of *Clavella* known to have a large (long) genital process as in the new species that protrudes much beyond the posterior margin of the trunk. They are: *C. adunca* (Strøm, 1762); *C. alata* Brian, 1906; *C. canaliculata* Wilson, 1915; *C. embiotocae* Dojiri, 1981; *C. irina* Wilson, 1915; *C. perfida* Wilson, 1915; and *C. tumida*. Having its trunk much wider than long, the new species differs from most of these species whose trunks are distinctly longer than wide. The trunks of *C. adunca* and *C. perfida* are about as long as wide or slightly longer than wide. Therefore, closer comparison needs to be made with these two species.

C. adunca is the most widely distributed species of *Clavella*. It has also been recorded from macrourids in Antarctic waters (Kabata & Gusev, 1966) and North Atlantic (Ho, 1985). However, the new species is distinguishable from this cosmopolitan species by the armatures of the antenna, mandible and maxillule. Unlike *C. sokodara*, the antenna of *C. adunca* is armed with small and weak spines terminally and lacks a basal seta on the outer surface of the second segment, its mandible bears secondary tooth and its maxillule carries a small exopod tipped with 2 small setae. Furthermore, the anchor on the bulla of *C. adunca* is ovate or clavate and not cup-like as in the new species.

The differences enumerated above for distinguishing *C. adunca* from *C. sokodara* by the structures of the antenna, mandible and maxillule also apply to a separation between it and *C. perfida*. Kabata (1970) provided distinguishing features between *C. adunca* and *C. perfida*.

3. *Clavella longicauda* new species

(Fig. 3)

Material examined. Fourteen females (some carrying a dwarf male) found on floor of oral cavity close to tip of mouth of 2 *Coryphaenoides marginatus* Steindachner & Döderlein collected off Okinawa. Holotype and 11 paratypes deposited in U. S. National Museum of Natural History; other specimens

kept in author's collection.

Female. Cephalothorax (Fig. 3A) subcylindrical, much longer than trunk, which is nearly twice longer than wide (Fig. 3B). Posterior surface of trunk (Fig. 3B) carrying a long genital process between attachment areas of egg sacs. Measurements of holotype: cephalothorax length 2.58, width 0.54; trunk length (not including genital process) 1.06, width 2.01; egg sac lengths 1.98 and 1.91.

Antennule as in *C. sokodara*, except for terminal armature showing one additional element (Fig. 3C). Antenna (Fig. 3D) indistinctly 3-segmented; first segment robust and unarmed, second segment carrying 2 basal setae on dorsal surface, and terminal segment protruded distally into an obtuse process in addition to bearing 3 sharp hooks and 1 denticulate spine. Dental formula of mandible (Fig. 3E) P1,S1,P1,S1-P1,S1,B2. Maxillule (Fig. 3F) short and robust, without spinulose area; exopod small, tipped with 2 unequal setae; papillae of endopod large, with each carrying a large seta. Maxillae (Fig. 3G) short and completely fused, with rather large basal protrusions carrying at their tip opening of excretory duct. Apical part of fused maxillae narrowed and without collar. Bulla slender and long (Fig. 3G), with very short manubrium. Maxilliped as in *C. sokodara*.

Male. Dwarf (Fig. 3H), only 413 μm in length.

Etymology. The species name *longicauda* alludes to the long genital process of this species.

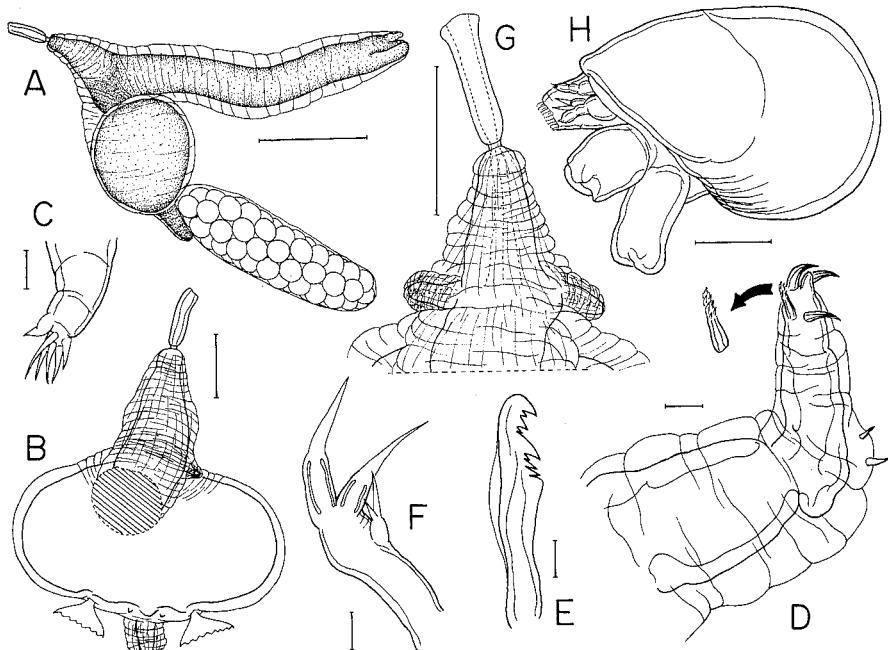


Fig. 3. *Clavella longicauda*, new species. Female: A. Habitus, lateral; B. Trunk, dorsal; C. Tip of antennule; D. Antenna; E. Mandible; F. Maxillule; G. Maxillae, posterior. Male: H. Habitus, lateral. Scales: 1 mm in A; 0.5 mm in B, G; 0.01 mm in C, D, E, F; 0.1 mm in H.

Remarks. This is the first species of *Clavella* with a trunk nearly twice as wide as long. The closest one is *C. sokodara*, whose trunk ratio (length/width) is 0.74. However, these two species can be easily separated by the structure of their maxillae (cf. Fig. 2G and Fig. 3G). Besides, the dental formula is also different between these two species.

Clavella deminuta Kabata, 1992 is another species with a relatively wide trunk (ratio=0.83). Interestingly, it is also known from the macrourid (*Coelorhynchus* sp.). Based on Kabata's (1992) original description, *C. deminuta* can be distinguished from the new species by the lack of genital process, presence of collar on the fused maxillae, lack of basal setae on the second segment of the antenna, and absence of secondary teeth on the mandible.

4. *Clavella okamurai* new species

(Fig. 4)

Material examined. Nineteen females attached to floor of oral cavity close to tip of mouth of 8 *Coryphaenoides marginatus* Steindachner & Döderlein collected off Okenawa. One female attached to gill raker of *Coryphaenoides nasutus* Günther collected from Sagami Bay. Holotype and 15 paratypes (collected off Okinawa) deposited in U. S. National Museum of Natural History; other specimens kept in the author's collection.

Female. Cephalothorax (Fig. 4A) subcylindrical, much longer than trunk and slightly inflated at base near attachment area of maxillae (Fig. 4B). Trunk (Fig. 4A) bilobate, projecting anterolaterally into a large blunt lobe on either side of base of cephalothorax (Fig. 4B). Posterior margin of trunk drawn out laterally (Fig. 4A), with areas of

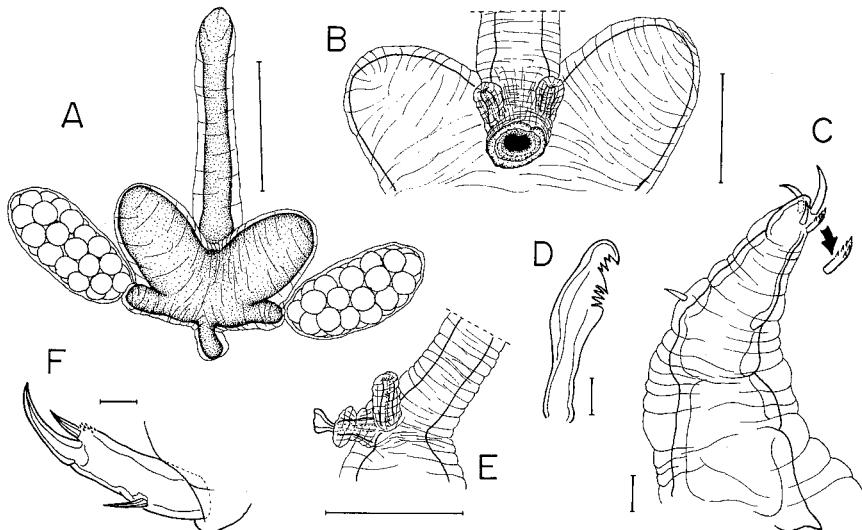


Fig. 4. *Clavella okamurai*, new species, female. A. Habitus, dorsal; B. Trunk, ventral; C. Antenna; D. Mandible; E. Maxillae, lateral; F. Tip of maxilliped. Scales: 1 mm in A; 0.5 mm in B, E; 0.01 mm in C, D, F.

egg-sac attachment set far apart and carrying a relatively large genital process at midway between these two areas. Measurements of holotype: cephalothorax length 1.87, width 0.37; trunk length along median axis (not including genital process) 0.67, width (between anterolaterally projecting lobes) 1.58; egg sac lengths 1.15 and 1.17.

Antennule and maxillule as in *C. sokodara* described above. Antenna (Fig. 4C) different from *C. sokodara* in armatures on basal surface of second segment and distal region of third segment. Terminal protrusion of third segment not as pronounced as in *C. sokodara*. Dental formula of mandible (Fig. 4D) P1,S1,P1,S1-P1,B3. Maxillae (Figs. 4B, 4E) very short, completely fused and forming distally a relatively large collar. Bulla clavate. Corpus of maxilliped as in *C. sokodara*, but armature on subchela and structure of terminal claw slightly different (Fig. 4F).

Male. Unknown.

Etymology. The species is named after the distinguished ichthyologist, Prof. Osamu Okamura, who made this study possible.

Remarks. In his study on the copepod parasites of Australian deep-sea fishes, Kabata (1992) described a species of *Clavella*, *C. tumidula*, with a unique feature of having ventral swellings on the trunk. The present new species adds another feature to this unusual development of trunk structure in *Clavella*. As in *C. tumidula*, one can separate the new species from its congeners by the shape of the trunk alone. Another uniqueness of *C. okamurai* is about the position of the egg sac attachment area. No other species of *Clavella* reported so far have such a widely separated oviducal openings. Due to the displacement of these openings, the egg sacs of *C. okamurai* are held in a manner much different from all other species. They are in a right angle, but not parallel, to the body axis.

5. *Clavella collaris* new species

(Fig. 5)

Material examined. Twenty females attached to gill filaments of 6 *Coelorhynchus paralleus* (Günther) collected off Okinawa and 3 females attached to gill filaments of 2 *Coelorhynchus giberti* Jordan & Hubbs collected from Tosa Bay. Holotype and 12 paratypes (collected off Okinawa) deposited in U. S. National Museum of Natural History; other specimens kept in author's collection.

Female. Cephalothorax (Fig. 5A) subcylindrical, much longer than trunk, which is either longer than wide (Fig. 5B) or squarish (Fig. 5C). Anal area protruded into a large lobe at posterior margin of trunk (Figs. 5B, 5C). Measurements of holotype: cephalothorax length 2.81, width 0.45; trunk length 2.21, width 1.36; egg sac lengths 4.54 and 4.62.

Antennule small, tipped with 6 elements as shown in Fig. 5D. Antenna (Fig. 5E) slightly curved, without armature on first two segments. Third segment protruded distally into a large lobe carrying ventrally a seta and a patch of denticles and dorsally 3 subterminal setae (Fig. 5F). Formula of mandible (Fig. 5G) 1P,1S,1P-1P,1S,2B. Maxillule (Fig. 5H) weakly developed; exopod represented by 2 small,

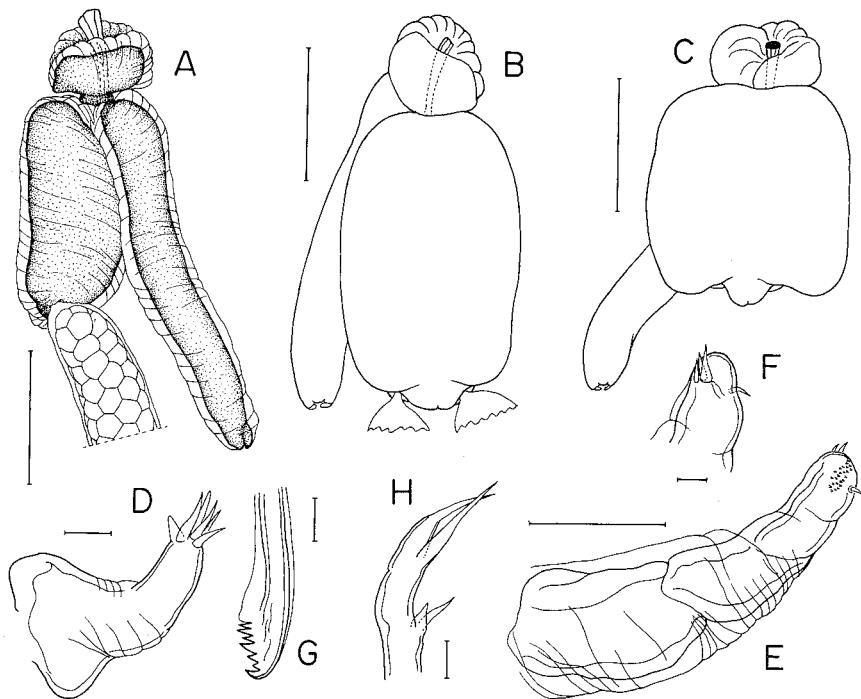


Fig. 5. *Clavella collaris*, new species, female. A. Habitus, lateral; B. Habitus of other specimen, ventral; C. Habitus of another specimen, ventral; D. Antennule; E. Antenna; F. Tip of antenna; G. Mandible; H. Maxillule. Scales: 1 mm in A, B, C; 0.01 mm in D, F, G, H; 0.05 mm in E.

unequal setae and endopod without usual prominent papillae. Maxillae (Figs. 5A, 5B, and 5C) extremely short, completely fused and forming distally a tremendously enlarged collar. Bulla clavate (Fig. 5A). Maxilliped as in *C. sokodara*.

Etymology. The species name *collaris* is from Latin “collare”. It alludes to the development of an unusually large collar in the present species.

Remarks. In addition to having an unusually large collar, the present new species is also distinguished in having a pair of extremely short maxillae. So far as I am aware, no species of *Clavella* possesses simultaneously these two states of maxillial character. Therefore, *C. collaris* can be easily identified with its maxillae alone.

It should be mentioned that *Clavella* sp. described by Kabata (1992: 28) from an Australian *Coelorhynchus* sp. has very large apical collar. Due to the scarcity of material, it was not fully described and kept anonymous. However, closer examination of what has been provided by Kabata suggests that it is perhaps not conspecific with *C. collaris*. Unlike the present species from Japan, the unnamed Australian *Clavella* has a moderately long maxillae.

6. *Clavella diversia* new species

(Fig. 6)

Material examined. Nine females attached to gill filaments of 6 *Coelorhynchus paralleus* (Günther) collected off Okinawa and 1 female attached to gill filament of *Coelorhynchus giberti* Jordan & Hubbs collected from Tosa Bay. Holotype and 6 paratypes (collected off Okinawa) deposited in U. S. National Museum of Natural History; other specimens kept in author's collection.

Female. Cephalothorax (Fig. 6A) subcylindrical, much longer than trunk, which is either oval (Fig. 6B) or subrectangular (Fig. 6C). Perianal region at posterior margin of trunk non-protruding and lacking genital process. Measurements of holotype (with subrectangular trunk): cephalothorax length 2.52, width 0.43; trunk length 1.34, width 1.12; egg sac lengths 3.32 and 3.18.

Antennule (Fig. 6D) short, with inflated base carrying a seta; terminal armature composed of 5 pointed setae and 1 obtuse process. Antenna (Fig. 6E) strongly bent between second and third segments, both of them unarmed; terminal segment protrude distally into a spinous process and bearing subterminally 3 spiniform setae on ventral

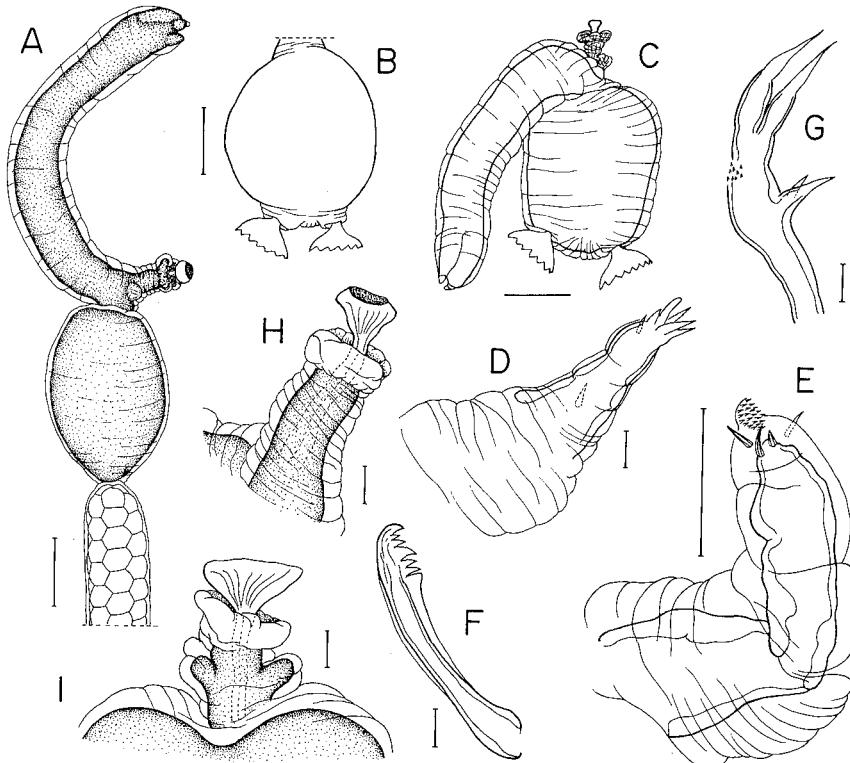


Fig. 6. *Clavella diversia*, new species, female. A. Habitus, lateral; B. Trunk, dorsal; C. Habitus of other specimen, dorsal (cephalothorax in lateral view); D. Antennule; E. Antenna; F. Mandible; G. Maxillule; H. Maxillae, lateral; I. Maxillae of other specimen, ventral. Scales: 0.5 mm in A, B, C; 0.01 mm in D, F, G; 0.05 mm in E; 0.1 mm in H, I.

surface and 1 seta on dorsal surface. Dental formula of mandible (Fig. 6F) P3-P1,B2. Maxillule (Fig. 6G) slender and weakly developed; exopod small carrying 2 unequal setae, endopodal papillae long and each tipped with a seta, inner distal surface of appendage carrying a patch of denticles but without seta. Maxillae short and completely fused, with (Fig. 6I) or without (Fig. 6H) lateral process. Apical part of fused maxillae forming a distinct collar. Bulla large, with funnel-shaped anchor. Maxilliped as in *C. sokodara*.

Male. Unknown.

Etymology. The species name *diversia* is taken from Latin "diversi", alludes to the various shapes of trunk and different appearance of the fused maxillae.

Remarks. This new species is characteristic in having an oval or subrectangular trunk with non-protruding perianal region without carrying a genital process. *C. diversia* shares this feature with eight species of its congeners. They are *C. applicata* Castro & Baeza, 1985; *C. bowmani* Kabata, 1962; *C. caudata* Castro & Baeza, 1985; *C. deminuta* Kabata, 1992; *C. ovata* Yamaguti, 1939; *C. scomropis* Yamaguti, 1939; *C. tumidula* Kabata, 1992; and *C. zini* Kabata, 1979. By lacking armature on the second segment of the antenna and a dental formula with P3 in the distal portion of the mandible, *C. diversia* is easily separated from most of them except for the three species discussed below. Interestingly, all of them are parasites of the macrourids.

As discussed above, *C. tumidula* is unique in having ventral swellings on its trunk and extremely reduced maxillae. Therefore, it is easily distinguished from the new species. The trunk of *C. deminuta* is unusual in carrying a pair of caudal rami on the posterior margin. The second antenna of this Australian species is straight, not strongly bent like that of *C. diversia*. The terminal armature of this appendage also differs between these two species, while there are four spiniform elements in *C. diversia*, the Australian species has only three.

C. zini was found on *Macrourus rufus* off Kermadec Islands (Kabata, 1979b). The major differences between it and *C. diversia* are seen in the terminal armatures of antennule and antenna. In *C. zini*, only 4 elements are found at the tip of the antennule and the terminal region of its antenna is not protruded into a spinous process and lacks a subterminal seta on its dorsal surface.

Acknowledgements

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